

# APPLICATION FOR UNITED STATES LETTERS PATENT

APPLICANT(S): MARTIN R. ELLIOTT  
MICHAEL R. RICE  
ROBERT B. LOWRANCE  
JEFFREY C. HUDGENS  
ERIC A. ENGLHARDT

TITLE: METHOD AND APPARATUS FOR  
SUPPLYING SUBSTRATES  
TO A PROCESSING TOOL

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**APPLIED MATERIALS, INC.**

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Name of person mailing papers: Valerie G. Dugan

Valerie G. Dugan 8/28/03  
Signature Date

DUGAN & DUGAN, P.C.  
18 John Street  
Tarrytown, New York 10591  
(914)332-9081

METHOD AND APPARATUS FOR SUPPLYING  
SUBSTRATES TO A PROCESSING TOOL

5       This application claims priority from United States provisional application Serial No. 60/407,336, filed August 31, 2002, the content of which is hereby incorporated by reference herein in its entirety.

FIELD OF THE INVENTION

10       The present invention relates generally to substrate processing, and more particularly to an apparatus and method for supplying substrates to a processing tool.

CROSS REFERENCE TO RELATED APPLICATIONS

15       The present application is related to the following commonly-assigned, co-pending U.S. Patent Applications, each of which is hereby incorporated by reference herein in its entirety:

20       U.S. Provisional Patent Application Serial No. 60/407,451, filed August 31, 2002 and titled "System For Transporting Wafer Carriers" (Attorney Docket No. 6900/L);

25       U.S. Provisional Patent Application Serial No. 60/407,339, filed August 31, 2002 and titled "Method and Apparatus for Using Wafer Carrier Movement to Actuate Wafer Carrier Door Opening/Closing" (Attorney Docket No. 6976/L);

30       U.S. Provisional Patent Application Serial No. 60/407,474, filed August 31, 2002 and titled "Method and Apparatus for Unloading Wafer Carriers from Wafer Carrier Transport System" (Attorney Docket No. 7024/L);

35       U.S. Provisional Patent Application Serial No. 60/407,452, filed August 31, 2002 and titled "End Effector Having

Mechanism For Reorienting A Wafer Carrier Between Vertical  
And Horizontal Orientations" (Attorney Docket No. 7097/L);

U.S. Provisional Patent Application Serial No. 60/407,337,  
5 filed August 31, 2002, and titled "Wafer Loading Station  
with Docking Grippers at Docking Stations" (Attorney Docket  
No. 7099/L);

U.S. Provisional Patent Application Serial No. 60/407,340,  
10 filed August 31, 2002 and titled "Wafer Carrier having Door  
Latching and Wafer Clamping Mechanism" (Attorney Docket No.  
7156/L);

U.S. Provisional Patent Application Serial No. 60/443,087,  
filed January 27, 2003 and titled "Methods and Apparatus for  
15 Transporting Wafer Carriers" (Attorney Docket No. 7163/L);

U.S. Patent Application Serial No. 60/407,463, filed August  
31, 2002 and titled "Wafer Carrier Handler That Unloads  
Wafer Carriers Directly From a Moving Conveyor" (Attorney  
20 Docket No. 7676/L).

U.S. Patent Application Serial No. 60/443,004, filed January  
27, 2003 and titled "Wafer Carrier Handler That Unloads  
Wafer Carriers Directly From a Moving Conveyor" (Attorney  
25 Docket No. 7676/L2).

U.S. Provisional Patent Application Serial No. 60/443,153,  
filed January 27, 2003 and titled "Overhead Transfer Flange  
and Support for Suspending Wafer Carrier" (Attorney Docket  
30 No. 8092/L);

U.S. Provisional Patent Application Serial No. 60/443,001,  
filed January 27, 2003 and titled "Systems and Methods for  
Transferring Wafer Carriers Between Processing Tools"  
35 (Attorney Docket No. 8201/L); and

U.S. Provisional Patent Application Serial No. 60/443,115,  
filed January 27, 2003 and titled "Apparatus and Method for  
Storing and Loading Wafer Carriers" (Attorney Docket No.  
5 8202/L).

#### BACKGROUND

Semiconductor devices are made on substrates, such  
as silicon substrates, glass plates or the like, often  
10 termed wafers, for use in computers, monitors, and the like.  
These devices are made by a sequence of fabrication steps,  
such as thin film deposition, oxidation, etching, polishing,  
and thermal and lithographic processing. Although multiple  
fabrication steps may be performed in a single processing  
15 apparatus, substrates typically must be transported between  
different processing tools for at least some of the  
fabrication steps.

Substrates are often stored in carriers for  
transfer between processing tools and other locations. In  
20 order to ensure that a processing tool does not idle, a  
nearly continuous supply of unprocessed substrates should be  
available to the tool. Thus, loading and storage  
apparatuses are conventionally located adjacent each  
processing tool. Such loading and storage apparatuses  
25 generally include one or more docking stations where  
substrate carriers are opened and individual substrates are  
extracted from the carriers and transported to a processing  
tool, as well as including a plurality of storage shelves  
positioned above the docking stations, a factory load  
30 location for receiving carriers at the loading and storage  
apparatus, and a robot adapted to transfer carriers among  
the factory load location, the docking stations and the  
plurality of storage shelves. The robot may include an end  
effector coupled to a support structure. Typically the  
35 support structure comprises a vertical guide and a

horizontal guide configured so that the end effector may move horizontally and vertically among the docking stations, the plurality of storage shelves and the factory load location.

5           The loading and storage apparatuses may be modularly designed (e.g. having components that are mounted to a frame typically extending in front of a single processing tool) or may be nonmodular in design (e.g., having components that may be mounted independently and  
10 typically having horizontal and/or vertical guides that extend in front of a plurality of processing tools).

          After a carrier is received at the factory load location, it may be moved by the robot from the factory load location to one of the storage shelves. Thereafter, the  
15 carrier may be moved from the storage shelf to a docking station. After the substrates have been extracted from the carrier, processed, and returned to the carrier, the carrier may be moved by the robot from the docking station to one of the storage shelves. Thereafter, the carrier may be moved  
20 by the robot from the storage shelf to the factory load location. Shuffling of the substrate carriers among the storage shelves, the factory load location and the docking station may place a significant burden on the robot, and may extend the period of time during which the substrates in the  
25 carrier are present in the factory without being processed. It accordingly would be desirable to streamline the handling of substrate carriers.

#### SUMMARY OF THE INVENTION

30           In a first aspect of the invention, a first method is provided for supplying substrates to a processing tool. The first method includes the steps of (1) providing a plurality of load ports each having a mechanism adapted to open a substrate carrier; (2) providing a factory exchange  
35 location at which substrate carriers are exchanged with a

substrate carrier transport device while the substrate carriers are in motion and being transported by the substrate carrier transport device; (3) providing a carrier handler having an end effector adapted to contact a  
5 substrate carrier, the carrier handler being adapted to transport substrate carriers between the factory exchange location and the plurality of load ports; and (4) receiving a first plurality of substrate carriers at the factory exchange location from the substrate carrier transport  
10 device. For each of the first plurality of substrate carriers, the method further includes the steps of (1) transporting the substrate carrier from the factory exchange location directly to a respective one of the plurality of load ports; (2) docking and opening the substrate carrier at  
15 the respective load port; (3) undocking and closing the substrate carrier at the respective load port; (4) transporting the substrate carrier from the respective load port directly to the factory exchange location; and (5) returning the substrate carrier to the substrate carrier  
20 transport device.

In a second aspect of the invention, a second method is provided for transferring a substrate carrier. The second method includes the steps of (1) conveying the substrate carrier on a substrate carrier conveyor positioned  
25 adjacent a substrate loading station that includes a substrate carrier handler adapted to transport the substrate carrier to a load port of a processing tool; (2) employing an end effector of the substrate carrier handler of the substrate loading station to disengage the substrate carrier  
30 from the substrate carrier conveyor while the substrate carrier is in motion and being transported by the substrate carrier conveyor; (3) transporting the substrate carrier from the substrate carrier conveyor directly to the load port; (4) docking and opening the substrate carrier at the  
35 load port; (5) undocking and closing the substrate carrier

at the load port; and (6) returning the substrate carrier directly to the substrate carrier conveyor.

In a third aspect of the invention, a third method is provided for transferring a substrate carrier to a substrate loading station. The third method includes conveying the substrate carrier on a substrate carrier conveyor positioned adjacent the substrate loading station. The substrate loading station comprises a substrate carrier handler adapted to transport the substrate carrier to a first load port of a processing tool, the substrate carrier handler including (1) a vertical guide; (2) a horizontal guide coupled to the vertical guide; and (3) an end effector adapted to support the substrate carrier and to move vertically relative to the vertical guide and horizontally relative to the horizontal guide.

The third method further includes (1) employing the end effector of the substrate carrier handler of the substrate loading station to disengage the substrate carrier from the substrate carrier conveyor; (2) transporting the substrate carrier from the substrate carrier conveyor directly to the first load port; (3) docking and opening the substrate carrier at the first load port; (4) undocking and closing the substrate carrier at the first load port; and (5) returning the substrate carrier directly to the substrate carrier conveyor. Numerous other aspects are provided, as are systems and apparatus in accordance with these and other aspects of the invention. The inventive methods may similarly provide for exchange, transport and placement of individual substrates (i.e., those not in or on a substrate carrier), with use of a substrate handler having an end effector adapted to contact and transport an individual substrate.

In accordance with the inventive methods and apparatus, a substrate/substrate carrier that is supplied to a processing tool is transferred directly from the factory

exchange location to a load port. The substrate/substrate carrier is transferred "directly" from the factory exchange location to a load port in the sense that it is transferred without the handler placing the substrate/substrate carrier  
5 on any support location other than a load port.

The inventive methods and apparatus provide for streamlined and highly efficient transfer of substrates and/or substrate carriers to and from processing tool load ports. Consequently, the total time required to transport  
10 and process substrates may be reduced, the costs and capital investment entailed in substrate work-in-process may be reduced, and burdens on substrate carrier handling robots may be diminished.

Further features and advantages of the present  
15 invention will become more fully apparent from the following detailed description of exemplary embodiments, the appended claims and the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

20 FIG. 1 is a top plan view of a conventional arrangement of a processing tool and associated substrate carrier loading and storage apparatus;

FIG. 2 is a front elevational view showing the conventional loading and storage apparatus of FIG. 1;

25 FIGS. 3A and 3B are front elevational views showing two exemplary embodiments of a substrate carrier loading apparatus provided in accordance with the invention;

FIG. 4 is a schematic plan view illustrating footprints of stacks of load ports shown in FIGS. 3A or 3B;

30 FIG. 5 is a schematic side view showing a substrate handler accessing load ports shown in FIGS. 3A or 3B; and

FIG. 6 is a flow chart that illustrates a manner of operating the inventive substrate carrier loading



apparatus of FIGS. 3A or 3B and an associated processing tool.

#### DETAILED DESCRIPTION

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#### RELEVANT TERMINOLOGY

As used herein, the term "docking" refers to the inward motion of a substrate or substrate carrier toward a port through which a substrate is exchanged, such as a port in a clean room wall. Similarly, "undocking" refers to the outward motion of the substrate or substrate carrier away from a port through which substrates are exchanged, such as a port in a clean room wall.

A "factory exchange location" includes all points in space at which a substrate or substrate carrier is handled by a device during removal of the substrate or substrate carrier from or placement of the substrate carrier on a substrate or substrate carrier transport device.

A "substrate or substrate carrier transport device" includes a conveyor, an automatic guided vehicle (AGV) or any other device that transfers substrates or substrate carriers to or from processing tool loading locations.

A "processing tool" comprises one or more processing chambers and one or more substrate handlers for loading and unloading the processing chamber. The substrate handlers may or may not be enclosed in chambers of their own such as factory interface chambers or transfer chambers. The processing chamber may perform a vacuum, atmospheric or other process on the substrate, including for example physical vapor deposition (PVD), chemical vapor deposition (CVD), etching, metrology, cleaning, polishing, etc.

A "load port" comprises a location where substrates or substrate carriers are placed for substrate transfer to and/or from a processing tool.

SYSTEM DESCRIPTION

FIG. 1 is a top plan view showing a conventional modular loading and storing apparatus 111 in position for storing carriers adjacent a conventional processing tool 113. FIG. 2 is a front elevational view showing the modular loading and storing apparatus 111. Referring initially to FIG. 1, a front end robot chamber 115 (or factory interface) is shown positioned between the loading and storage apparatus 111 and the processing tool 113. As shown in FIG. 1 the loading and storage apparatus 111 is positioned adjacent a first side of a clean room wall 117 and the front end robot chamber 115 is positioned adjacent a second side of the clean room wall 117. The front end robot chamber 115 contains a robot 119 that may move horizontally along a track (not shown) so as to extract substrates from the loading and storage apparatus 111 and transport them to a loadlock chamber 121 of the processing tool 113. The loading and storage apparatus 111 comprises a pair of loading stations 123 where substrate carriers are placed for substrate extraction (in this example the loading stations are equipped with docking movement and are therefore referred to as docking stations), and a plurality of storage shelves 201 (best shown in FIG. 2) positioned above (e.g., at a higher elevation than) the docking stations 123. The storage shelves 201 are mounted on a support frame 203. Also mounted on the support frame 203 is a substrate carrier handling robot 205. The robot 205 includes a vertical guide 207 on which an end effector 209 is mounted for vertical motion. The vertical guide 207 is mounted for horizontal motion along a horizontal guide 211. A factory load location 213 for receiving substrate carriers is positioned between the docking stations 123.

By virtue of the vertical guide 207 and the horizontal guide 211, the end effector 209 of the substrate

carrier handling robot 205 is able to move substrate carriers among the factory load location 213, the storage shelves 201 and the docking stations 123. However, as noted before, shuffling of substrate carriers from the factory load location 213 to the storage shelves 201, then to the docking stations 123, and back to the factory load location 213 (possibly via the storage shelves 201) may result in a significant amount of time being consumed in supplying substrates to the processing tool 113, thereby increasing the quantity of work-in-process.

FIG. 3A is a schematic front elevational view of an exemplary substrate loading station provided in accordance with the present invention. Reference numeral 301 generally indicates the inventive substrate loading station. The loading station 301 includes a plurality of load ports 303. Preferably each load port 303 has a docking mechanism (not shown) such as a motorized gripper or platform adapted to support a substrate carrier and adapted to move the substrate carrier toward and away from the opening through which a substrate is to be transferred. In the particular embodiment illustrated in FIG. 3A, the load ports 303 are arranged in two stacks 305, 307 of three load ports each. Thus a total of six load ports 303 are present in the embodiment of FIG. 3A. Other numbers and/or arrangements of load ports may be employed. The stack 307 is positioned spaced apart from and to a side of the stack 305. Each load port 303 may include a mechanism, generally represented by reference number 309, for opening substrate carriers docked at the load ports 303. In one embodiment of the invention, the load ports 303 are adapted to receive single substrate carriers. The term "single substrate carrier" refers to a substrate carrier shaped and sized to contain only one substrate at a time. In general, the load ports 303 may accommodate any type of substrate carrier (e.g., a single substrate carrier, a multi-substrate

carrier, a front opening substrate carrier, a front opening unified pod, a combination thereof, etc.). FIG. 3A shows substrate carriers 311 docked at two of the load ports 303.

In one embodiment, each load port 303 is adapted to open a substrate carrier 311 simultaneously with substrate carrier docking (e.g., the movement of the carrier toward the port in the clean room wall). Such opening may be achieved for example via a cam and follower arrangement. A load port of this type is disclosed in previously incorporated, co-pending U.S. patent application Serial No. 60/407,339, filed August 31, 2002 and titled "Method and Apparatus for Using Wafer Carrier Movement to Actuate Wafer Carrier Door Opening/Closing" (Attorney Docket No. 6976/L). Alternatively, conventional door opening devices (e.g., that open a carrier after it has been docked) may be employed. Such devices conventionally employ a door receiver that unlocks the carrier door and removes it from the carrier to allow substrate extraction.

A substrate carrier transport device, such as a conveyor (schematically illustrated at 313) is configured to deliver substrate carriers to, and to remove substrate carriers from, the inventive substrate loading station 301. Associated with the inventive loading station 301 and positioned adjacent to the conveyor 313 is a substrate carrier exchange device 315 which is adapted to receive substrate carriers from the conveyor 313 and to deliver substrate carriers to the conveyor 313. Accordingly, it will be recognized that the substrate carrier exchange device 315 defines a factory exchange location 317 at which substrate carriers are exchanged with the conveyor 313. The substrate carrier exchange device 315 may be, for example, of the type shown in previously incorporated U.S. patent application Serial No. 60/407,451, filed August 31, 2002 and titled "System For Transporting Wafer Carriers" (Attorney Docket No. 6900/L) which discloses a rotating platform that

rotates so as to contact and couple/decouple a substrate carrier to or from the overhead factory transport system.

As another alternative, the substrate carrier exchange device 315 may be of the type disclosed in co-

5 pending U.S. patent application Serial No. 09/755,394

(Attorney Docket No. 5092) which discloses an elevating member that extends linearly upward so as to contact and couple/decouple a substrate carrier to or from the overhead factory transport system (and which is hereby incorporated

10 by reference herein in its entirety). As still another

alternative, the substrate carrier exchange device 315 may be of the type disclosed in previously incorporated U.S.

patent application Serial No. 60/407,474, filed August 31, 2002 and titled "Method and Apparatus for Unloading Wafer

15 Carriers from Wafer Carrier Transport Systems" (Attorney Docket No. 7024/L which discloses a rotary arm that rotates so as to contact and couple/decouple a substrate carrier to or from the overhead factory transport system. In yet a

further alternative, the substrate carrier exchange device

20 may be omitted, and the carrier handler may exchange

substrate carriers with the carrier transport device 313 at the factory exchange location (e.g., any location where carriers are exchanged between the inventive loading station and the carrier transport device). Such a method is

25 described in detail in co-pending U.S. patent application

Serial Nos. 60/407,463, filed August 31, 2002 (Attorney Docket No. 7676/L) and 60/443,004, filed January 27, 2003

(Attorney Docket No. 7676/L2).

The substrate carrier exchange device 315 may be

30 configured, for example, to remove substrate carriers from the conveyor 313 while the conveyor (or a carrier

transported thereon) is in motion, and to deliver substrate carriers to the conveyor 313 while the conveyor (or a substrate carrier transporter traveling therealong) is in

35 motion. Thus it may be practical to maintain the conveyor

313 in continuous motion while the semiconductor fabrication facility is in operation, thereby improving transportation of substrates through the fabrication facility, reducing the amount of time required for each particular substrate to  
5 traverse the fabrication facility, and thereby reducing the total number of substrates present as work-in-process, at any given time.

The inventive loading station 301 further includes a carrier handler 319. The carrier handler 319 includes an  
10 end effector 321 that is adapted to contact the substrate carriers 311. For example, the end effector 321 may be adapted to support the substrate carriers 311 from the bottom, or to grip the substrate carriers 311 from the top, etc.

15 The end effector 321 is adapted to move vertically along a vertical guide 323. The vertical guide 323, in turn, is adapted to move horizontally along a horizontal guide 325. Consequently, the end effector 321 is movable among the factory exchange location 317 and all of the load  
20 ports 303. It will also be appreciated that the end effector 321 is movable vertically in a space 327 that is between the stacks 305, 307 of load ports 303. In one alternative the vertical and horizontal guides may be repositioned as shown in FIG. 3B, such that the end effector  
25 321 may be adapted to move horizontally along the horizontal guide 325 and such that the horizontal guide 325 moves vertically along the vertical guide 323. Though not shown in FIGS. 3A or 3B, the inventive load station may include one or more storage shelves for storing substrates and/or  
30 substrate carriers.

FIG. 4 is a schematic top plan view illustrating features of the layout of the inventive loading station 301. In FIG. 4, reference numeral 117 indicates the clean room wall. Reference numeral 401 indicates the footprint of the  
35 stack 305 of load ports 303. Reference numeral 403

indicates the footprint of the stack 307 of load ports 303. It is to be understood that the "footprint" of an item is the projection of the item on the floor of the facility. Reference numeral 405 indicates an area between the  
5 footprints 401 and 403. A tool "envelope" of the inventive loading station should be understood to mean the footprints 401 and 403 plus the area 405 between the footprints 401 and 403. Reference numeral 407 indicates the tool envelope defined by the stacks 401 and 403.

10           The carrier handler 319 may operate such that it moves substrate carriers 311 only within the envelope defined by the footprints 401, 403 of the load port stacks 305, 307. A controller C controls the operation of the carrier handler 319 and is programmed such that the carrier  
15 handler operates in accordance with the invention as described in detail with reference to the flow chart of FIG. 6.

Referring again to FIGS. 3A or 3B, it will be observed that the factory exchange location 317 is at a  
20 height that is greater than respective heights of the load ports 303. It will also be observed that the factory exchange location 317 and the stack 305 of load ports 303 have substantially the same footprint. However, other arrangements of the inventive loading station 301 are  
25 contemplated. For example, the factory exchange location 317 may be at or below the height of the load ports 303. Also, the footprint of the factory exchange location 317 may coincide with the footprint 403 (FIG. 4) of the stack 307 of load ports 303. As another alternative, the footprint of  
30 the factory exchange location 317 may not coincide with either one of the footprints 401, 403 of the stacks 305, 307 of load ports 303.

FIG. 5 is a schematic side view showing a substrate handler in relation to a conventional processing  
35 tool 113 and stacked load ports 303 of the inventive loading

station 301 (FIGS. 3A OR 3B). Referring to FIG. 5, reference numeral 501 indicates a substrate handler provided in accordance with the invention. The inventive substrate handler 501 may be selectively positioned at a lower  
5 position (indicated by reference numeral 503), at which the inventive substrate handler 501 can be moved horizontally to access a lowest one of the stacked load ports 303. The inventive substrate handler 501 can also be selectively  
10 positioned at an upper position (indicated in phantom and represented by reference numeral 505) at which the inventive substrate handler 501 can be moved horizontally to access the uppermost of the stacked load ports 303. It will be appreciated that the inventive substrate handler 501 may also be selectively positioned at any intermediate position  
15 (not specifically indicated in the drawing) that is between the indicated positions 503 and 505, for example, at a position at which the inventive substrate handler 501 can be moved horizontally to access a middle one of the stacked load ports 303.

20 As used herein, a substrate handler is said to "access" a load port when the substrate handler extends into the load port area (e.g., to transport a substrate).

It will be appreciated that, after the inventive substrate handler 501 removes a substrate (not shown) from a  
25 substrate carrier 311 (FIGS. 3A OR 3B, not shown in FIG. 5) docked to one of the stacked load ports 303, the inventive substrate handler 501 may supply the substrate to the processing tool 113, or, more specifically, to a load lock chamber 121 (FIG. 1, not separately shown in FIG. 5) of the  
30 processing tool 113.

FIG. 6 is a flow chart that illustrates operation of a substrate loading station configured in accordance with the present invention, such as the inventive substrate loading station 301 of FIGS. 3A or 3B. A controller C may



be coupled to the substrate loading station and operative to perform one or more steps of the process of FIG. 6.

According to a first step 601 in FIG. 6, a substrate carrier 311 is received at the factory exchange location 317. In the exemplary substrate loading station 301 of FIGS. 3A or 3B, for example, the carrier exchange device 315 removes a substrate carrier 311 from the conveyor 313 (e.g., via the end effector 321). This may occur, for example, while the conveyor 313 is in motion.

Following step 601 in FIG. 6 is step 603. At step 603 the carrier handler 319 transports the substrate carrier 311 from the factory exchange location 317 to one of the load ports 303. In accordance with the invention the substrate carrier 311 is transported directly from the factory exchange location 317 to one of the load ports 303. That is, the carrier handler 319 does not place the substrate carrier 311 at any carrier support location other than one of the load ports 303 after removing the substrate carrier 311 from the factory exchange location 317 and before placing the substrate carrier 311 at one of the load ports 303.

Following step 603 in FIG. 6 is step 605. At step 605, the substrate carrier 311 is docked and opened at one of the load ports 303 at which it was placed by the carrier handler 319. As noted above, the load port 303 may be adapted such that docking and opening of the substrate carrier 311 occurs simultaneously.

Step 607 follows step 605 in FIG. 6. At step 607, the substrate handler 501 extracts a substrate from the substrate carrier 311 that has been docked at and opened by one of the load ports 303. The extracted substrate is then supplied to the processing tool 113 by the substrate handler 501, and processing of the substrate (step 609) occurs within the processing tool 113.

After processing of the substrate in the processing tool 113 is complete, the substrate handler 501 returns the substrate to the substrate carrier 311 that was docked and opened at one of the load ports 303 (step 611).

5 Then the substrate carrier 311 in which the processed substrate was inserted is closed and undocked from the load port 303 (step 613). The undocking and closing of the substrate carrier 303 may occur simultaneously. Following step 613 in FIG. 6 is step 615. At step 615 the carrier  
10 handler 319 transports the substrate carrier 311 from the load port 303 to the factory exchange location 317. According to an aspect of the invention, the substrate carrier 311 may be transported directly from the load port 303 to the factory exchange location 317. That is, the  
15 substrate carrier 311 may be transported from the load port 303 to the factory exchange location 317 without being placed on any carrier support location after being removed from the load port 303 and before being delivered to the factory exchange location 317.

20 Following step 615 in FIG. 6 is step 617. At step 617, the carrier exchange device 315 returns the substrate carrier 311 to the conveyor 313. In one embodiment of the invention, this may be done while the conveyor 313 is in motion. It should be noted that the steps of docking and/or  
25 opening the substrate carrier may be omitted in systems that transport individual substrates, or that do not require substrates to be docked. Accordingly steps 605 and 613 are optional. It will be understood that the inventive method may be performed with individual substrates rather than  
30 substrate carriers. Additional figures directed to the transportation of individual substrates rather than substrate carriers between the carrier transport device and the processing tool are not included so as to avoid repetition.

The methods and apparatuses of the present invention are advantageous in that transportation of the substrate carriers to and from the load ports is streamlined, so that the total time of transit of substrates through the semiconductor fabrication facility may be reduced. This, in turn, may translate into reduced work-in-process, lower capital costs, and a reduced manufacturing cost per substrate.

The foregoing description discloses only exemplary embodiments of the invention; modifications of the above disclosed methods and apparatuses which fall within the scope of the invention will be readily apparent to those of ordinary skill in the art. For example, the carrier handler described above in connection with FIGS. 3A or 3B includes a vertical guide that is movable horizontally along a single horizontal guide. It is, however, also contemplated to employ a carrier handler of the type in which a vertical guide is slidably mounted between two parallel horizontal guides. As still another alternative, there may be employed a carrier handler of the type in which a horizontal guide is slidably mounted on one or more vertical guides. Of course, other types of carrier handlers including those that do not use linear guides may be employed.

It is also contemplated to employ other configurations of load ports besides the two stacks of three load ports each shown in FIGS. 3A or 3B. For example, there may be only two load ports in each stack of load ports, or, there may be four or more load ports in each stack of load ports. It is also not required that the same number of load ports be provided in each stack of load ports. As still another alternative, only one stack of load ports may be provided, or three or more stacks of load ports may be provided. Note also, that although each stacked loadport is shown as occupying the same footprint, other arrangements with partially overlapping footprints or non-overlapping

footprints may be employed. There may be embodiments where a single load port is employed, or where two or more horizontally adjacent load ports are employed.

It is noted that FIG. 5 shows a single substrate handler that is configured to service all of the load ports in a stack of load ports. As possible alternatives, a respective substrate handler may be provided to service each load port. It is also contemplated that a single substrate handler may be employed to service all of the load ports of more than one stack of load ports. It is further contemplated that a respective substrate handler be provided for each stack of load ports.

Substrate carrier transport devices other than the conveyor 313 may be employed to bring substrate carriers to, and transport substrate carriers away from, the factory exchange location. If a conveyor is employed as the substrate carrier transport device, it may optionally be kept continuously in motion while the semiconductor fabrication facility is operating.

Although only one factory exchange location is shown in association with the inventive substrate loading station, it is contemplated to provide two or more factory exchange locations in association with the inventive substrate loading station. For example, a first factory exchange location may be employed for incoming substrate carriers, and a second factory exchange location may be employed for outbound substrate carriers. It is also contemplated that an inventive substrate loading station may be served by more than one substrate carrier transport device.

Preferably, the invention is employed in a substrate loading station that comprises a frame to which the vertical and horizontal guides are coupled. In this manner, the preferred substrate loading station is modular and may be quickly installed and calibrated. In the event

the substrate loading station includes one or more storage shelves, each storage shelf also may be mounted on the frame. By mounting both the substrate carrier handler and the storage shelf or shelves to the frame, the substrate carrier handler and storage shelves have a predetermined position relative to each other. This further facilitates installation and calibration, and is another advantage of employing a modular substrate loading station. Similarly, other mechanisms such as dedicated mechanisms for loading and/or unloading substrate carriers from an overhead factory transport system may be advantageously mounted to the frame. Exemplary dedicated mechanisms may comprise rotating platforms or rotating arms, etc., as described in previously incorporated U.S. Patent Application Serial Nos. 60/407,451, filed August 31, 2002 and 60/407,474, filed August 31, 2002 (Attorney Docket Nos. 6900 and 7024).

In one aspect, the frame may be mounted to predetermined mounting locations (e.g., predrilled bolt holes, etc.) on the clean room wall, or on the front wall of a chamber (e.g., a factory interface chamber). Preferably, the wall also has predetermined mounting locations to which the docking grippers or docking platforms are mounted. Additionally, the wall may have predetermined mounting locations to which a substrate carrier opening mechanism may be mounted. When the frame, the docking mechanisms, and the substrate carrier opening mechanism are each mounted to predetermined locations on the same surface, the relative positions of each are predetermined, and installation and calibration of the substrate loading station is facilitated.

The present invention has been illustrated in connection with single substrate carriers. However, it is also contemplated to apply the present invention in connection with substrate carriers that hold more than one substrate, or to apply the invention in connection with transport of individual substrates (not transported via

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carriers). As will be apparent, the inventive apparatus may differ considerably from the exemplary embodiments shown and described herein. Any apparatus that operates in accordance with the method of FIG. 6 (whether or not docking and opening are performed, and whether or not substrate carriers are employed (e.g., individual substrate systems)) may fall within the scope of the present invention.

Accordingly, while the present invention has been disclosed in connection with a preferred embodiment thereof, it should be understood that other embodiments may fall within the spirit and scope of the invention, as defined by the following claims.